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Thick Oil Detection by Remote Sensing

Visible oil slicks vary in thickness by 7 or more orders of magnitude sometimes on spatial scales of meters or less. Wave damping that can be observed by SAR occurs for oil slicks thicker than 0.1 – 1 μm, and can be visibly detected at ~1 μm. As a result, positive oil slick detection fails to provide guidance to responders, as slicks thicker than 100 μm generally are needed to justify response approaches based on performance needs and ecological damage. With respect to response needs, the most urgent relate to identifying thick oil to appropriately task response assets. Quantified oil thickness would provide additional benefits in cases where the amount of spilled oil remains unknown to ensure assets are sufficient and based on spatial maps and models, that more sensitive at risk areas are appropriately protected.

Experienced airborne eyes remains the current preferred approach, where spatial patterns and appearance provide the information critical to identify false positives and thick oil. However, logistics and limited trained personnel have strongly motivated development of remote sensing approaches, both active and passive. Most passive approaches use reflected solar radiation or thermal emissions; active uses laser or radar. Radar is all-weather, 24/7. Passive thermal and lidar performs under clouds, while passive visible requires clear sunny skies.

Passive Reflective Multispectral (Pattern Recognition): Unfortunately, oil slick appearance in the visible and near infrared is dominated by thin film effects and saturates once absorption dominates over sky reflection (~10 μm thickness). Analysis is further complicated because oil slicks in nature almost always occur as oil-water emulsions, with the water content having a larger effect on appearance than thickness. Thus, successful passive visible thickness detection uses trained intelligent systems on standard RGB images. However, such systems produce false positives and negatives if the training set was inappropriate or inadequate. In general, most satellite instrument spatial resolutions are too coarse, while for platforms with sufficiently high resolution (e.g. Worldview-2), infrequent revisit and limited swath reduce utility. Although targetable orbital sensors overcome these limitations, passive targetable systems remain uncommon.

Passive Emissive (Thermal): Far more reliable is thermal radiation, with sheens largely being invisible to in the thermal to most current sensors, and thick oil (>150 μm) exhibiting observable thermal deviations from surrounding water. Where thermal anomalies are more several degrees centigrade, the oil likely is thicker than 500 μm. False positives can be significant due to non-oil thermal anomalies from oceanographic effects, like convergence zones. Current satellite thermal instruments resolutions generally are greater than for passive instruments, making thick oil detection more difficult, although for sufficiently thick oil, satellite thermal is more definitive than satellite passive at discriminating thick oil. A number of suitable airborne thermal sensors have been deployed successfully, some in an operational capacity. Because current thermal detection relies solely on thermal contrast, multispectral thermal sensors do not convey an advantage.

Passive Reflective Hyperspectral: Hyperspectral data extending into the SWIR is the only approach currently shown to quantify oil thickness for thick oil slicks (> 150 μm) by taking advantage of oil adsorption features around 1650 and 2300 nm, providing a diagnostic oil signature. This was demonstrated for the NASA AVIRIS (airborne visual infrared imaging spectrometer) during the Deepwater Horizon spill using a spectral library approach. The relationship between absorption feature strength and thickness cannot be solved unless the effect of water, which alters the feature shape, is considered. Satellite hyperspectral data from the EO-1 mission, Hyperion, has limited swath at high (30 m) resolution, 16 day revisit, and must be tasked, but covers the same spectral range as AVIRIS, and thus has potential for space-based thicknesses remote sensing.

Synthetic Aperture Radar (SAR): SAR has the highest sensitivity to oil detection through observing subtle changes in the wave field due to the presence of oil; however, many non-oil factors can create the same wave field changes, leading to false positive detection. Although wave field changes do not provide information related to oil thickness, the latest SAR instruments (e.g. the NASA UAVSAR) have sufficient signal to noise and fidelity to map surface dielectric changes that are related to oil thickness. This holds out the promise of 24/7, all-weather oil thickness mapping for airborne SAR instruments and for next generation targetable satellite SAR (with resolutions to 1 m).

Lidar: Lidar fluorescence provides a diagnostic signal that has been related to sheen oil thickness, up to 15 μm. As sheens of this thinness have little response interest, lidar generally has not been used in oil spill response, except as an airborne validation of satellite SAR identified potential oil slicks.